REMARKS

The title has been amended for simplification. The present amendments to the claims include cancellation of claim 23, to avoid claim duplication. Other amendments were made for the purpose of improving claim readability and compliance with formal requirements for claims. Process claim 19 was made to be dependent from claim 1. After entry of the amendments, claims 1-22 and 24-37 will be pending for examination.

In the Office Action, all of the claims were made subject to a restriction requirement, the applicants being required to elect one of the following groups:

I. The compounds and composition according to claim 1; and

II. The process of preparing according to claim 19.

Applicants are interpreting this requirement as including all of claims 1-18 in Group I, and all of claims 19-29 in Group II. Claims 30-37 pertain to the amorphous levocetirizine dihydrochloride compound and its compositions, so presumably also fall within Group I.

Restriction was predicated on a holding that other products can be made using the claimed process. However, applicants do not believe that the current state of the art would support this holding.

Several recent articles have reported various aspects of the phenomenon of pharmaceutical compound polymorphism. Among these is A. Goho, "Tricky Business," *Science News*, Vol. 166, pages 122-3 (August 21, 2004), and an eight-page website reprint of the article is enclosed. Those skilled in the art are aware from this and other publications that: it is not possible to predict whether a particular compound has more than one polymorphic form; it is not possible to predict the number of polymorphic forms of a compound that will be discovered; and there is no predictable way to proceed toward preparing a new form of a compound. The article also reports that seemingly minor alterations to a process can give rise to the formation of a previously unknown polymorphic form.

In addition to the lack of scientific support for the restriction, applicants submit that the requirement does not comply with Office guidelines for restriction. As set forth in M.P.E.P. § 803:

> If the search and examination of an entire application can be made without serious burden, the examiner must examine it on the merits, even though it includes claims to independent or distinct inventions.

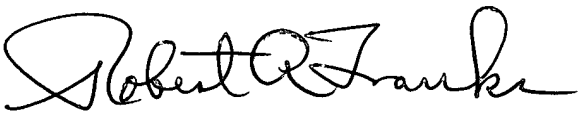
The two "inventions" are classified in the same class. Further, all of the claims of this application relate to a single chemical compound, so the same search will necessarily be employed to examine the two "inventions." Processes for preparing a different compound will not be relevant to determining patentability of the claims for preparing amorphous levocetirizine dihydrochloride, as shown by the A. Goho article. There can be no undue burden involved in a single examination of all of the pending claims, and the restriction requirement should be withdrawn.

However, if the requirement is maintained, applicants elect the compound and composition claims of Group I for the initial examination.

CONCLUSION

Entry of the amendments and withdrawal of the restriction requirement is respectfully solicited. If any minor issues remain to be resolved, please contact the undersigned to arrange for a telephonic or personal interview so that resolution can be obtained in the most expeditious manner.

Respectfully submitted,



Robert A. Franks
Reg. No. 28,605
Attorney for Applicants

February 17, 2006

Dr. Reddy's Laboratories, Inc.
200 Somerset Corporate Blvd., Seventh Floor
Bridgewater, New Jersey 08807-2862
Telephone 908-203-6504
Facsimile 908-203-6515

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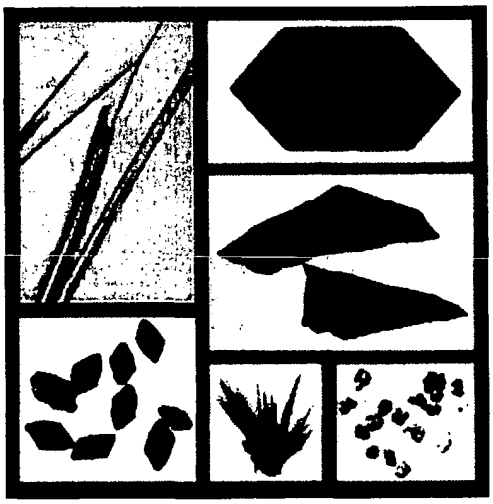
Tricky Business

The crystal form of a drug can be the secret to its success

Alexandra Goho

In one of Kurt Vonnegut's science fiction novels, a scientist creates a form of ice that doesn't melt until it reaches 114.4°F. Called Ice-9, this imaginary crystal takes over the world, as all of Earth's waters, and life itself, freeze solid. What endows Ice-9 with such unusual properties is the unique configuration of the stacked water molecules. Although Ice-9 of *Cat's Cradle* (1963, Holt, Rinehart and Winston) is pure fantasy, the concept of a molecule assuming multiple crystal structures—or polymorphs—is real, and the consequences can be dramatic. One polymorph of carbon provides black and slippery graphite, another is hard, transparent diamond. A blue pigment used in ink-jet printers has either a red or green tint, depending on the pigment's crystal structure. Even crystallized cocoa butter has different polymorphs; some cause the chocolate to melt in your mouth more quickly than others.

In recent years, the pharmaceutical industry has increasingly focused its attention on polymorphs. There's plenty of incentive. The precise arrangement of molecules within the crystal of a drug determines how fast it dissolves in the body and how much enters the bloodstream. Polymorphs of a drug differ in properties that affect its shelf life or ease of manufacture. A newly discovered polymorph may turn out to be a more effective and convenient than the original product.



TRUE COLORS. The organic compound dubbed ROY can adopt six different crystal structures, or polymorphs, ranging from yellow needles to orange-red plates. ROY is currently the world record holder for having the largest number of fully characterized polymorphs.
Yu

The Food and Drug Administration requires all companies to register the precise polymorph of any drug that they produce. Pharmaceutical manufacturers also have to demonstrate that each polymorph is stable and can be reproduced reliably. Otherwise, it would be hard to set a drug's effective dosage. "The FDA has very strict regulations on this," says Jerry Atwood of the University of Missouri-Columbia.

Regulations aside, drug companies are becoming increasingly aware that different polymorphs can translate into more or less profit. Because each polymorph is legally defined as a unique, patentable composition of matter, a company that develops a new drug will patent all the polymorphs that it has discovered and produced.

That, however, affords the patent holder only limited business protection. Because the science behind polymorphs remains murky, there's no guarantee that a competitor won't discover a new polymorph of the drug that's better than the patented ones.

The world of polymorphs also opens up complicated business strategies. For example, when a patent is set to expire, a company might have other patents related to a drug's polymorphs that make it difficult for competitors to produce generic versions.

Situations such as these have fueled intense litigation over the years. "The polymorph issue is so important to the pharmaceutical industry," says Atwood. "We're talking about multibillion-dollar drugs. Ultimately, it comes down to a hard legal battle."

It also comes down to fundamental chemistry. Polymorphism has elicited enough excitement and fear in the drug business that a growing number of researchers in academia and in private companies are taking a closer look at how crystals grow, and what these scientists discover could shape an entire industry.

Disappearing act

Emblematic of the importance of polymorphs is the cautionary tale of ritonavir, the AIDS drug made by Abbott Laboratories. Introduced in 1996, the drug had been on the market for 18 months when suddenly, during manufacturing, chemical engineers detected a previously unknown polymorph. No one knew what had caused the change, but the scientists discovered that the new polymorph was thermodynamically stabler than the drug in its original form. The Abbott team couldn't find a way to stop formation of the new polymorph. Within a few days of its discovery, this new polymorph was dominating the product coming off the lines, says Sanjay Chemburkar, one of the Abbott chemists involved in the situation.

Although the two polymorphs shared a chemical formula, their structural dissimilarity made a difference to patients. The second form was only half as soluble as the first, so patients taking prescribed doses wouldn't get enough of the drug into their bloodstreams. Abbott pulled ritonavir from the market.

"The company went on a crash program to try to get their [original] polymorph back," says Atwood. Abbott eventually succeeded in producing the first form again, but it could not make the polymorph reliably and kept getting mixtures of the two forms. The company finally decided to reformulate the drug in the second polymorphic form as a liquid gel capsule containing the predissolved drug. Unlike the original formulation of the drug, the gel capsules require refrigeration.

"Abbott lost a lot of money over this," says Allan Myerson of the Illinois Institute of Technology in Chicago. The company spent hundreds of millions of dollars trying to recover the first polymorph and lost an estimated $250 million in sales the year the drug was withdrawn.

Cases such as this aren't routine, but they're common enough for drug companies to be concerned about the surprises that polymorphism can bring, says Myerson.

Screening for polymorphs early on is always best, says Patrick Stahly. He's the chief operating officer at SSCI, a contract research laboratory in West Lafayette, Ind., that specializes in crystal screening and analysis. Even so, drug companies often wait until late in the development process before thoroughly screening for polymorphs. "We've had clients come to us in the middle of human clinical trials after discovering their drug had two different polymorphs," says Stahly. Such a company has to regain control over its manufacturing

process and start the trials over using a single polymorph.

That experience underscores one way that companies can get bitten by polymorphism. There are other potential pitfalls as well.

Consider ranitidine hydrochloride, the anti-ulcer drug owned by the drug giant GlaxoSmithKline and known by millions as Zantac. In the mid-1990s, as the patent on the drug was approaching expiration, other companies began gearing up to market cheaper, generic versions. By marketing drugs that have gone off patent, generics manufacturers skip human trials, the most expensive part of the drug-development process.

However, GlaxoSmithKline—which was simply Glaxo at the time—had in its pocket a patent on a second polymorph of the drug. The company discovered that second form early in the processing of the first form. Glaxo didn't receive a patent on the second form until nearly 7 years after receiving the initial drug patent. Because the second form was easier to manufacture, it became the active ingredient in Zantac.

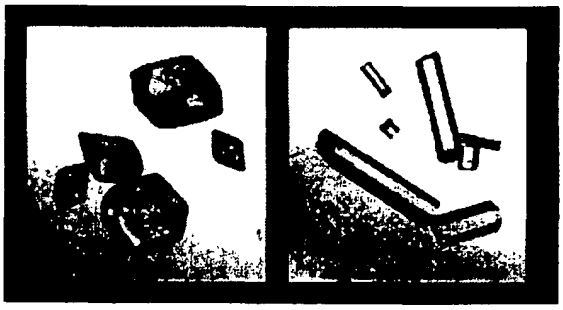
Although other companies were legally permitted to make and sell generic versions of the first polymorph of ranitidine hydrochloride, they had to figure out how to make it without any contamination from the second, whose patent protection remained in force. This kept the generic companies products off the market for several years.

"Zantac was the largest-selling drug in the world," says Joel Bernstein of Ben-Gurion University of the Negev in Beer Sheva, Israel. Bernstein was an expert witness for Glaxo when a dispute over its original patent went to court. Glaxo was making $10 million in sales each day on its ulcer treatment, so every day it retained control over its drug was significant.

Crystal fate

The conventional approach to finding polymorphs begins with old-fashioned crystallization experiments. First, dissolve the drug in a solvent. Next, cool the solution or evaporate the solvent, coercing the drug molecules to stick together to form crystals. Varying the temperature of the solution and using different solvents are among the long-used tricks for getting the molecules to stack in different geometries.

Trying to discover new polymorphs in the lab can be frustrating. "Sometimes they show up, sometimes they don't," says Adam Matzger of the University of Michigan in Ann Arbor. "There is very little in the way of new approaches to finding polymorphs."



POLYMER RELIEF. Growing crystals of the pain-relieving drug acetaminophen on different polymer surfaces will yield different crystal structures. One polymer gives rise to tiny prisms (left); another, miniature monoliths (right). Z. Tolstyka

In search of ideas, researchers have been exploring factors other than temperature and solvent that might influence crystallization and produce polymorphs. For instance, SSCI is investigating a technique developed by Myerson. Two years ago, he and his colleagues found that intense pulses of near-infrared light could affect the crystallization of the amino acid glycine. When the light was linearly polarized, so that its

electric field vibrated in one direction, the crystal grew as one polymorph; when the light was circularly polarized, so that the electric field rotated, it induced a second polymorph.

Myerson suspects that the electric field generated by the light influences how the glycine molecules arrange themselves as they aggregate into small clusters early in the crystallization process.

The instructions for growing into a particular type of polymorph are imprinted on the cluster by the time it reaches a critical size containing tens to hundreds of molecules. Once these nuclei form, the "fate of the system has been decided," says Michael Ward of the University of Minnesota in Minneapolis.

Different packings of molecules lead to nuclei of different sizes, which in turn yield different polymorphs. So, Ward wondered whether confining a dissolved compound to a given space would limit the size of a nucleus that could form and force the molecules to pack in a specific polymorphic arrangement. As they reported in the March 24 *Journal of the American Chemical Society*, he and his colleagues tested this hypothesis by growing crystals within porous materials.

The Minnesota team turned to blocks of polymer with cylindrical pores 30 nanometers in diameter. To this material, the researchers added a solution of an organic chemical commonly used in the manufacture of pharmaceuticals. This compound, dubbed ROY, is currently the world record holder for having the most—six—fully characterized polymorphs. However, Ward and his colleagues found that only one form of ROY crystallized inside the pores.

Ward notes that the fine details of surfaces also play a role in crystallization. Think of rock candy. "When you dissolve sugar in water and put a stick in the container, where does the candy grow? On the stick," he says.

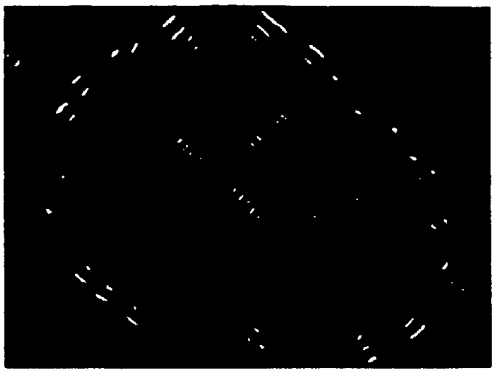
Matzger, for one, has found that growing crystals of the same compound on different polymer materials can produce different polymorphs. The Michigan group crystallized the pain-relieving drug acetaminophen, which is known to have two polymorphs, on 84 different polymer materials. They found that certain materials, such as nylon and polyvinyl chloride—the plastic used in plumbing—induced one form to grow, while other polymers, such as cellulose, favored the other form.

Next, the researchers did a similar experiment with carbamazepine, an antiepileptic drug with three known crystal structures. Not only did all three polymorphs show up, but also a new and previously unknown polymorph grew on 4 of the 84 polymers. Matzger speculates that the precise way in which a polymer's atoms are arranged near the surface could favor the growth of certain polymorphs.

While pharmaceutical firms might use strategies like these to discover new polymorphs, once a company lands on a desirable crystal form of a drug, it faces other challenges. To make large quantities, researchers often seed batches of the dissolved drug with a small grain of the desired polymorph, expecting the grain to nucleate the growth of much larger crystals of the same polymorph.

That strategy usually works, but sometimes it doesn't.

"The engineers will often say to me: 'The polymorphism of this drug is out of control. I seed with this crystal and I get something else,'" says pharmaceutical chemist Lian Yu.



BAD SEED. Two different polymorphs of the sugar mannitol were detected with a spectral-imaging technique. The two crystal structures scatter radiation differently, producing a unique pattern of black and white bands. The image shows how one polymorph of mannitol (inner pattern) can cause a second polymorph (outer pattern) to grow on its surface. J. Am. Chem. Soc.

While working at Eli Lilly and Company in Indianapolis, Ind., Yu discovered that the surface of one crystal structure sometimes induces a different polymorph. In the May 28, 2003 *Journal of the American Chemical Society*, Yu describes an experiment in which he used a polymorph of the sugar mannitol to seed a dissolved solution of the sugar. The polymorph that started forming on the surface of that crystal was a different one altogether.

Yu, who is now at the University of Wisconsin–Madison, suspects that this process could be at the heart of many incidents, such as Abbott's ritonavir saga, in which researchers at drug-manufacturing plants suddenly find they can no longer grow the polymorph they want. Some unrecognized change in the manufacturing process might have altered whether the growing crystals model themselves after their seed crystals.

Forecasting

In 1965, a Chicago microscopist named Walter C. McCrone stated the following maxim regarding the art of crystal growing: "The number of forms known for a given compound is proportional to the time and money spent in research on that compound."

Consider ROY. It took Yu and his colleagues many years to produce all six forms, which they first reported in 2000. The colorful diversity of the different crystal structures—which range from red needles to orange plates to yellow prisms—and the fact that they all form at room temperature "really has captured the imagination of the community," says Yu.

Other compounds, however, do not support McCrone's rule. Aspirin, for example, has been crystallized by the tons for decades under many different conditions, and yet only one crystal form has ever emerged, says Sally Price at University College London. "People are fairly confident that there aren't any more to be found," she says.

Yet without extensive studies, there is no way to entirely discount the possibility that some sets of conditions could lead to polymorphs of aspirin. "Right now, you can't predict polymorphs, and you can't predict their properties," says Atwood.

Such forecasting might be possible in the future. Last fall, Price and her collaborators launched a multimillion-dollar research initiative to develop computer software tools that consider the arrangement of atoms within a compound to predict whether that compound is likely to take on different crystal structures and, if so, approximately how many.

A company might use such predictions to find that one of its drug molecules has other stable polymorphs. If so, the company would aggressively search for those polymorphs. The

predicted crystal structures would also give researchers ideas for methods to produce the polymorphs in the lab.

Alternatively, the predictions might suggest that the polymorph in hand is the stablest form and that other forms are unlikely to arise. The company could then save the time and money that would otherwise be spent on unnecessary screening experiments.

At the moment, Price says her team can make predictions only for very simple molecules. "Most pharmaceuticals are far more complicated," she says. It could be a decade before such computer predictions can be applied to drug development. In the meantime, the specter of sudden polymorphism will remain a fact of life for pharmaceutical firms.

If you have a comment on this article that you would like considered for publication in *Science News*, send it to editors@sciencenews.org. Please include your name and location.

References:

Bernstein, J. 2002. *Polymorphism in Molecular Crystals*. New York: Oxford University Press.

Chemburkar, S.R., *et al.* 2000. Dealing with the impact of ritonavir polymorphs on the late stages of bulk drug process development. *Organic Process Research and Development* 4(September):413-417.

Childs, S.L. . . . and G.P. Stahly. 2004. A metastable polymorph of metformin hydrochloride: Isolation and characterization using capillary crystallization and thermal microscopy techniques. *Crystal Growth and Design* 4(May):441-449.

Garetz, B.A., J. Matic, and A.S. Myerson. 2002. Polarization switching of crystal structure in the nonphotochemical light-induced nucleation of supersaturated aqueous glycine solutions. *Physical Review Letters* 89(Oct. 21):175501. Abstract available at http://link.aps.org/abstract/PRL/v89/e175501.

Ha, J.-M. . . . and M.D. Ward. 2004. Polymorph selectivity under nanoscopic confinement. *Journal of the American Chemical Society* 126(March 24):3382-3383.

Lang, M., A.L. Grzesiak, and A.J. Matzger. 2002. The use of polymer heteronuclei for crystalline polymorph selection. *Journal of the American Chemical Society* 124(Dec. 18):14834-14835.

Price, S.L. 2004. The computational prediction of pharmaceutical crystal structures and polymorphism. *Advanced Drug Delivery Reviews* 56(Feb. 23):301-319. Abstract available

at http://dx.doi.org/10.1016/j.addr.2003.10.006.

Yu, L. 2003. Nucleation of one polymorph by another. *Journal of the American Chemical Society* 125(May 28):6380-6381.

Yu, L., *et al.* 2000. Thermochemistry and conformational polymorphism of a hexamorphic crystal system. *Journal of the American Chemical Society* 122(Feb. 2):585-591.

Further Readings:

Davey, R.J. 2003. Pizzas, polymorphs and pills. *Chemical Communication* 13(June 12):1463-1467. Available at http://dx.doi.org/10.1039/b303125j.

Dunitz, J.D., and J. Bernstein. 1995. Disappearing polymorphs. *Accounts of Chemical Research* 28(April):193-200.

Grzesiak, A.L. . . . and A.J. Matzger. 2003. Comparison of the four anhydrous polymorphs of carbamazepine and the crystal structure of form I. *Journal of Pharmaceutical Sciences* 92(November):2260-2271. Abstract available at http://dx.doi.org/10.1002/jps.10455.

McCrone, W.C. 1963. Polymorphism. In *Physics and Chemistry of the Organic Solid State*, D. Fox, M.M. Labes, A. Weissberger, eds. New York: Interscience Publishers.

Mitchell, C.A., L. Yu, and M.D. Ward. 2001. Selective nucleation and discovery of organic polymorphs through epitaxy with single crystal substrates. *Journal of the American Chemical Society* 123(Nov. 7):10830-10839.

Price, C.P. . . . and A.J. Matzger. 2003. Maize 1: A trimorphic azo pigment. *Crystal Growth and Design*. 3(November):1021-1025.

Price, C.P. . . . and A.J. Matzger. 2002. Polymorphism of nabumetone. *Crystal Growth and Design* 2(November):501-503.

Vonnegut, K. 1963. *Cat's Cradle*. New York: Holt, Rinehart & Winston.

Sources:

Jerry Atwood
Department of Chemistry
University of Missouri, Columbia
601 South College Avenue
Columbia, MO 65211

Joel Bernstein
Department of Chemistry
Ben-Gurion University of the Negev
P.O. Box 563
Beer-Sheva 84105
Israel

Sanjay R. Chemburkar
Process Development and Analytical Research
Abbott Laboratories
1401 Sheridan Road
North Chicago, IL 60064-6291

Adam Matzger
Department of Chemistry
University of Michigan, Ann Arbor
930 N. University
Ann Arbor, MI 48109-1055

Allan Myerson
Department of Chemical and Environmental Engineering
Illinois Institute of Technology
Room 103 Siegel Hall
Chicago, IL 60616-3793

Sally L. Price
Centre for Theoretical and Computational Chemistry
Department of Chemistry
University College London
20 Gordon Street
London WC1H 0AJ
United Kingdom

Patrick Stahly
SSCI, Inc.
3065 Kent Avenue
West Lafayette, IN 47906-1076

Michael Ward
Department of Chemical Engineering and Materials Science
University of Minnesota
Amundson Hall
421 Washington Avenue, SE
Minneapolis, MN 55455

Lian Yu
School of Pharmacy
University of Wisconsin, Madison
777 Highland Avenue
Madison, WI 53705-2222

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